A Framework for Combining Long and Short Time-Scale Traffic Engineering for MPLS

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1. Introduction

Proposed frameworks for traffic engineering for emerging networks, including MPLS, can be classified into long time scale and short time scale schemes [1]. In long time scale the admission control and routing algorithms respond to slow variations in the average loads to guarantee close to optimal performance under quasi-stationary conditions [2]-[3]. In short time scale the state-dependent admission control and routing algorithms take into account the available bandwidth in order to provide fast adaptation to abrupt changes in the operating conditions [4]. Since long time scale schemes usually lack robustness under changing conditions, and short time scale schemes usually under perform under steady conditions, there is a need for combining both schemes to optimize the performance/robustness curve under wide range of the operating conditions. This paper proposes such combined admission control and routing scheme for a connection-oriented network. Despite generalization to a multi-service case is possible, due to limited space we assume a single service case. The proposed scheme is a two-step procedure. The first step is an adaptive admission and routing scheme, which adapts to slow variations in average loads by estimating corresponding implied costs [2]-[3]. At this stage the admission and routing scheme selects a route from the predetermined set of primary routes. No alternate routes are allowed. Since the first-step admission and routing decisions are based on the average loads only and no alternate routes are allowed, the call may find that the selected route does not have sufficient available bandwidth to carry this call. The second step provides second opportunity for this call to be admitted on one of the secondary routes. This second-stage admission and routing decisions are based on the instantaneous available bandwidth and provide fast adaptation to abrupt changes in the operating environment.

2. Traffic Engineering Scheme

Consider a connection-oriented, loss network with N nodes, L links $l \in L$ and suppose that link l comprises C_l circuits. Calls with origin-destination (n,k) arrive as a Poisson stream of rate λ_{nk}. A call accepted on route r simultaneously occupies and holds one circuit on each link $l \in r$ for the holding period of the call. The call holding period is a random variable with unit mean and independent of earlier arrivals and holding times. The network performance is characterized by the rate of return from the network. Assuming that each accepted call with origin-destination (n,k) generates revenue with rate w_{nk} the steady-state rate of return from the network is

$$W = \sum_{(n,k)} w_{nk} \lambda_{nk} (1 - \pi_{nk})$$

where π_{nk} is the steady-state blocking probability for a call with origin-destination (n,k). We propose the following two-stage call admission and routing strategy. At the first stage the admission and routing for an arriving call with origin-destination (n,k) is determined by a probability distribution $\{q_r, r \subset R^1_{nk}\}$ on a set of primary routes R^1_{nk} with origin-destination (n,k), where $q_\Sigma = \sum_{r \subset R^1_{nk}} q_r \le 1$.

Here probabilities q_r do not depend on the link occupancies, but may depend on the network parameters, i.e., arrival rates and link capacities. An arriving request is carried on a route $r \subset R^1_{nk}$ selected with probability q_r if each link $l \in r$ has at least one available circuit. At this stage the call is rejected with probability $q_0 = 1 - q_\Sigma$. If some route $r \subset R^1_{nk}$ was selected at the first stage, but at least one link on this route is completely occupied, the admission and routing decision process proceeds to the second stage. At the second stage the request can be admitted on one of a secondary route of minimum cost $r_* \subset R^2_{nk}$:

$D_* = D_{r_*} = \min_{r \in R_{nk}^2} D_r$, if this minimum cost does not exceed the revenue brought by the request: $D_* \le w$, and the request is rejected otherwise. The set of primary routes is typically a subset of the set of secondary routes: $R_{nk}^1 \subseteq R_{nk}^2$.

The main our contribution is developing cost function D_r. The revenue generated by the network is $W = W^1 + W^2$ where the revenue brought by the calls accepted at the first stage is W^1, and the revenue brought by the calls accepted at the first stage is W^2. We make the following two assumptions: first, that the sets of primary and secondary routes are sufficiently diverse, and, second, that $W^2 << W^1$. First assumption is conventional and allows us to approximately decompose the network into the set of independent links [2]-[3]. Second assumption introduces "small parameter" $\varepsilon = W^2 / W^1$ and makes derivation of the "optimal" cost function D_r tractable.

The final result is as follows. Following [2] define the implied cost of a link $l \in L$:

$$c_l = \frac{\partial}{\partial C_l} W^1(\lambda, C)$$

where the vector of request arrival rates for all origin-destination pairs (n,k) is $\lambda = (\lambda_{nk})$, and the vector of link $l \in L$ capacities C_l is $C = (C_l)$. Following [5] define the following function

$$d(i,\nu,C) = \frac{\nu^C / C!}{\nu^i / i! + (\nu - i) \sum_{k=i+1}^{C} (\nu^k / k!)}$$

where $i \in \{0,1,..,C\}$ and $\nu \ge 0$. We show that under listed assumptions the cost of a route r is additive

$$D_r = \sum_{l \in r} D_l(\nu_l, x_l)$$

where the rate of primary requests on link l is ν_l, and the number of occupied circuits on link l is x_l. The cost of a link l is

$$D_l(\nu, x) = g_l(\nu) d(x, \nu, C_l)$$

where

$$g_l = \frac{c_l / \nu_l}{E(\nu_l, C_l - 1) - E(\nu_l, C_l - 1)}$$

and Erlang probability is

$$E(\nu, C) = \frac{\nu^C}{C!} \Big/ \sum_{n=0}^{C} \frac{\nu^n}{n!}$$

References

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